drought tips

Number 92-20

Water Balance Irrigation Scheduling Using CIMIS ET_o

CIMIS is an integrated network of more than 80 computerized weather stations located at key agricultural and municipal sites throughout California. The system is operated by the California Department of Water Resources. CIMIS helps agricultural growers and managers of large turfgrass areas such as parks and golf courses develop water budgets for determining when to irrigate and how much water to apply.

The purpose of irrigation is to replace soil water losses not replaced by rainfall, fog, groundwater, or other water sources. Applications are normally timed to replace water before yield-reducing water stress occurs. Since water losses occur mainly through crop evapotranspiration (ET_c), accurate estimates of ET_c are needed for efficient irrigation management, especially for low-volume (drip, microsprinkler) and sprinkler irrigation systems.

Potential (maximum) ET_c depends on the weather and on plant and management factors. Reference evapotranspiration (ET_o) allows for the effects of weather, increasing and decreasing according to evaporative demand. Crop coefficient (k_c) estimates allow for plant and management factors including crop age, height and roughness, and irrigation frequency during early crop growth. Potential ET_c is calculated as:

$$ET_c = ET_o \times K_c$$

When a crop is deficit irrigated — that is, when irrigation replaces only some, but not all of the soil water loss— plant water stress occurs, lowering ET_c below potential ET_c. In most crops, this practice reduces yield and should normally be avoided..

Drought Tip 92-54 gives historical average ET_o rates by region, but since current weather and evaporative demand may differ from historical averages, the California Irrigation Management Information System (CIMIS) provides current ETo information for most major agricultural regions of the state. Using ET_o from CIMIS improves estimates of ETc by allowing for fluctuations in current weather. Since using CIMIS to determine ET_c can often improve crop yield and stretch water supplies, CIMIS data can be particularly useful during drought.

How to Obtain CIMIS Information

Some water districts, newspapers, and radio stations retrieve and disseminate CIMIS information. Check with local water agencies, University of California farm advisors, resource conservation districts, or the USDA Soil Conservation Service for information on local sources.

CIMIS data are available through a computer dial-up service linked directly to the CIMIS computer in Sacramento. The CIMIS computer has a complete database of all stations currently operating in the network from the time the station was established to the most recent previous midnight. It has hourly, daily, weekly, and monthly values for the entire period of record of any station and also contains historical data from all stations that have been discontinued.

CIMIS data are also available by computer access through the California State University computer system called the Advanced Technology Information Network (ATI-NET) computer system. Information can be obtained through the main campus computers in Arcata, Bakersfield, Carson, Chico, Fresno, Fullerton, Hayward, Long Beach, Los Alamitos, Los Angeles, Northridge, Pomona, Rohnert Park, Sacramento, San Bernardino, San Diego, San Francisco, San Luis Obispo, San Jose, and Turlock.

An inexpensive terminal or microcomputer, telephone modem, and communication software, available from virtually all computer outlets, is all that is needed to get data from CIMIS or ATI-NET. Both computer systems require an assigned identification "login ID" and "password" to access information. To obtain a free login ID and password to retrieve data from the CIMIS computer, write to:

Department of Water Resources
Water Conservation Office
P.O. Box 942836
Sacramento, CA 94236-0001

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For access to ATI-NET information, write to:

ATI-NET
California Agricultural
Technology Institute
California State University, Fresno
2910 East Barstow Avenue
Fresno, California 93740-115

Irrigation Timing

Irrigation timing — when to irrigate a crop — can be determined by first setting a management allowable depletion (MAD), which is the maximum amount of moisture that can be depleted from the soil without reducing crop yield.

The MAD represents the difference between field capacity (the water content after excess water has drained from the soil — usually the soil water content one or two days after an irrigation or heavy rainfall) and the measured or estimated actual soil water content (soil water depletion).

The first irrigation is scheduled for the date preceding the day when the soil water depletion from evapotranspiration exceeds the MAD. See Drought Tip 92-62 for information on selecting a MAD.

Example 1: Scheduling with Historical ET_o

The easiest way to schedule irrigations is to use a database or spreadsheet computer program. However, many growers have developed successful scheduling plans using hand-held calculators, paper and pencil. Table 1 is an example for a *single field* irrigation schedule based on *historical average ET_o rates* for a potato crop planted on February 1.

Historical ET_o and potato K_c values for the San Joaquin Valley were entered for the entire season, but only the month of April is shown. For our scheduling example, a management allowable depletion (MAD) equal to 2.0 inches and a field capacity (FC) equal to 8 inches were used to time irrigations. When the soil water content is at field capacity (full), the soil water depletion equals zero (SWD=0). Since we wanted to start at field capacity for our example, the soil water content (column 7) was set at field capacity (8 inches) on March 31. Often the starting point occurs after a thorough wetting of soil by pre-irrigation or winter rainfall. If this is not the case, the initial soil water content should be determined by field observation.

Table 1 lists the calendar day in column 1, and the corresponding daily ET_o rate is entered into column 2. Historical average daily ET_o rates can be selected from the 10-day averages given in Drought Tip 92-54. Estimated daily K_c values are entered into column 3. Information on K_c values for major California crops is given in Drought Tips 92-44, 92-45, 92-46, 92-47, and 92-48. Calculated ET_c rates (the product of columns 2 and 3) are listed in column 4.

Column 5 shows the soil water (SW) content on each day. It is determined by subtracting ET_c (column 4) from the previous day's adjusted soil water (Adj. SW Content (column 7). Column 6 is used to enter contributions to crop water needs supplied by irrigation, rainfall, fog, or groundwater. A corrected soil water content (column 7) is calculated by adding the contributions in column 6 to the soil water content in column 5. Normally, an irrigation will return the soil water content to field capacity and the value in column 7 will equal field capacity following an irrigation.

To illustrate the calculation procedure in Table 1, consider the schedule from April 12-17. The SW content (column 5) on April 13 equals 6.23 inches. This value is calculated by subtracting 0.16 inches for April 13 (column 4) from the 6.38 inches for April 12 (column 7). There is no contribution to soil water on April 13, so the adjusted SW content (column 7) on April 13 is 6.23 inches. The SW content (column 5) on April 14 is 6.06 inches (6.23 from column 7 minus 0.16 from column 4). At the current ET_c rate, the soil water depletion will exceed the MAD (2 inches) on the next day. Therefore, an irrigation is needed on April 14 and a net application of 1.94 inches is entered into column 6. This results in an adjusted SW content (column 7) equal to 8.00 inches. On April 15, the SW content in column 5 equals 7.83 inches (8.00 from column 7 minus 0.17 from column 4). There is no contribution on April 15, so the adjusted SW content also equals 7.83 inches. On April 16, the SW content equals 7.66 inches (7.83 from column 7 minus 0.17 from column 4). There is no contribution to soil water on April 16, so the adjusted SW content is also 7.66 inches. On April 17, the SW content equals 7.48 inches (7.66 from column 7 minus 0.18 from column 4), but there is a contribution of 0.25 inches from rainfall, fog, or a water table that increases the adjusted SW content to 7.73 inches (7.48 from column 5 plus 0.25 from column 6). This procedure is continued throughout the schedule.

The example in Table 1 is for a single field; separate tables are needed for additional fields requiring schedules. In many cases, fields with the same crop are irrigated sequentially during an irrigation cycle. A single schedule for the first field can often be used with little loss in accuracy for the remaining fields in the same irrigation cycle.

Example 2: Scheduling with CIMIS ET_o

Using the spreadsheet approach described using Table 1, a schedule can be easily updated substituting current CIMIS ET_o data for the historical ET_o values. For example, Table 2 is the same as Table 1, except that the historical ET_o was replaced for this example with the April 1990 CIMIS ET_o data from the Shafter Field Station and the schedule was refigured. The ET_o figures from 1990 (Table 2) are higher than the historical average ET_o values (Table 1) and therefore irrigations occur a few days earlier in Table 2. In some cases more irrigation applications are needed when current CIMIS ET data are used and in other cases fewer irrigations will be required, which, in either case, illustrates that using current CIMIS can result in more precise irrigation management.

Amount to Apply

Once the question of *when* to irrigate has been answered, the question of *how much* water to apply is addressed. Water is normally applied as evenly as possible to a field, but some may run off the surface or drain (percolate) below the root zone.

The amount of water to apply is calculated by dividing the measured or estimated soil water depletion by the application efficiency — which is the ratio of the water applied and stored in the root zone for use in evapotranspiration to the total water applied. Contact your local farm advisor or USDA-SCS office for information on how to determine application efficiency.

Because the water is applied unevenly, the total water applied should be greater than the soil water depletion to ensure that portions of the field receiving the least amount of water are adequately irrigated. At each irrigation, the total water to apply (AW) should be recalculated as:

$$AW = SWD \div AE \qquad (1)$$

where SWD is the current soil water depletion and AE is the application efficiency. For example, if the depletion below field capacity is 2 inches and the application efficiency is 0.80, then 2.5 inches ($= 2 \div 0.80$) should be applied to ensure that most of the field receives at least 2 inches of water.

References

Bowers, W.O., R.L. Snyder, S.B. Southard, and B.J. Lanini. 1989. *Water-holding characteristics of California soils.* University of California Leaflet 21463.

Faber, B. and R.L. Snyder (1992) *Central Coast Valleys evapotranspiration and crop coefficients for field crops.* University of California Drought Tip 92-48.

Schulbach, K. and R.L. Snyder (1992) *Central Coast Valleys evapotranspiration and crop coefficients for field crops.* University of California Drought Tip 92-45.

Snyder, R.L. (1992) *Fog contributions to plant water needs.* University of California Drought Tip 92-40.

______________. (1992). *Averages of reference evapotranspiration (ETo) for California.* University of California Drought Tip 92-54.

Snyder, R.L. and K. Bali (1992) *North Coast Valleys evapotranspiration and crop coefficients for field crops.* University of California Drought Tip 92-44.

______________. (1992) *Sacramento Valley evapotranspiration and crop coefficients for field crops.* University of California Drought Tip 92-46.

______________. (1992) *San Joaquin Valley evapotranspiration and crop coefficients for field crops.* University of California Drought Tip 92-47.

Snyder, R.L., S.R. Grattan, and H.L. Sheradin. 1992. *Selecting a management allowable depletion (MAD).* University of California Drought Tip 92-62.

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Table 1. Water balance irrigation schedule during April for potatoes planted February 1 *using historical ETo* for Shafter in the San Joaquin Valley with MAD equal to 2 inches and field capacity equal to 8 inches.

Day	ET_o	K_c	ET_c	SW content	Contributions to soil water	Adj. SW Content
	in.		in.	in.	in.	in
31						8.00
1	0.13	0.96	0.12	7.88		7.88
2	0.13	0.96	0.12	7.75		7.75
3	0.13	0.97	0.13	7.63		7.63
4	0.13	0.97	0.13	7.50		7.50
5	0.13	0.97	0.13	7.37		7.37
6	0.14	0.98	0.13	7.24		7.24
7	0.14	0.98	0.13	7.10		7.10
8	0.14	0.99	0.14	6.97		6.97
9	0.14	0.99	0.14	6.83		6.83
10	0.14	1.01	0.14	6.68		6.68
11	0.14	1.03	0.15	6.54		6.54
12	0.14	1.05	0.15	6.38		6.38
13	0.15	1.07	0.16	6.23		6.23
14	0.15	1.10	0.16	6.06	1.94	8.00
15	0.15	1.12	0.17	7.83		7.83
16	0.15	1.14	0.17	7.66		7.66
17	0.15	1.16	0.18	7.48	0.25	7.73
18	0.16	1.18	0.18	7.55		7.55
19	0.16	1.20	0.19	7.36		7.36
20	0.16	1.20	0.19	7.17	0.68	7.85
21	0.16	1.20	0.19	7.65		7.65
22	0.16	1.20	0.20	7.45		7.45
23	0.17	1.20	0.20	7.26		7.26
24	0.17	1.20	0.20	7.05		7.05
25	0.17	1.20	0.20	6.85		6.85
26	0.17	1.20	0.21	6.64		6.64
27	0.17	1.20	0.21	6.43		6.43
28	0.18	1.20	0.21	6.22		6.22
29	0.18	1.20	0.21	6.01	1.99	8.00
30	0.18	1.20	0.22	7.78		7.78

1. Net irrigation amount
2. Net rainfall amount